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ABSTRACT

The experimental project which resulted in this manual utilized an electronic calculator to aid in mathematics instruction in the 11th and 12th grades. The requirements for implementing the program are described and illustrated by the experiences at the pilot school. A curriculum guide is given for the inservice teacher training program. Suggestions for using the calculator in a mathematics program includes a curriculum outline, suggested instructional materials, and a list of instructional objectives described in behavioral terms. A bibliography contains an annotated list of calculator projects and research studies, and articles from recent publications. (JY)

UTILIZING an ELECTRONIC CALCULATOR

A MANUAL for PLANNING and DEVELOPMENT

SUFFOLK COUNTY

REGIONAL CENTER

FOR SUPPLEMENTARY EDUCATIONAL SERVICES

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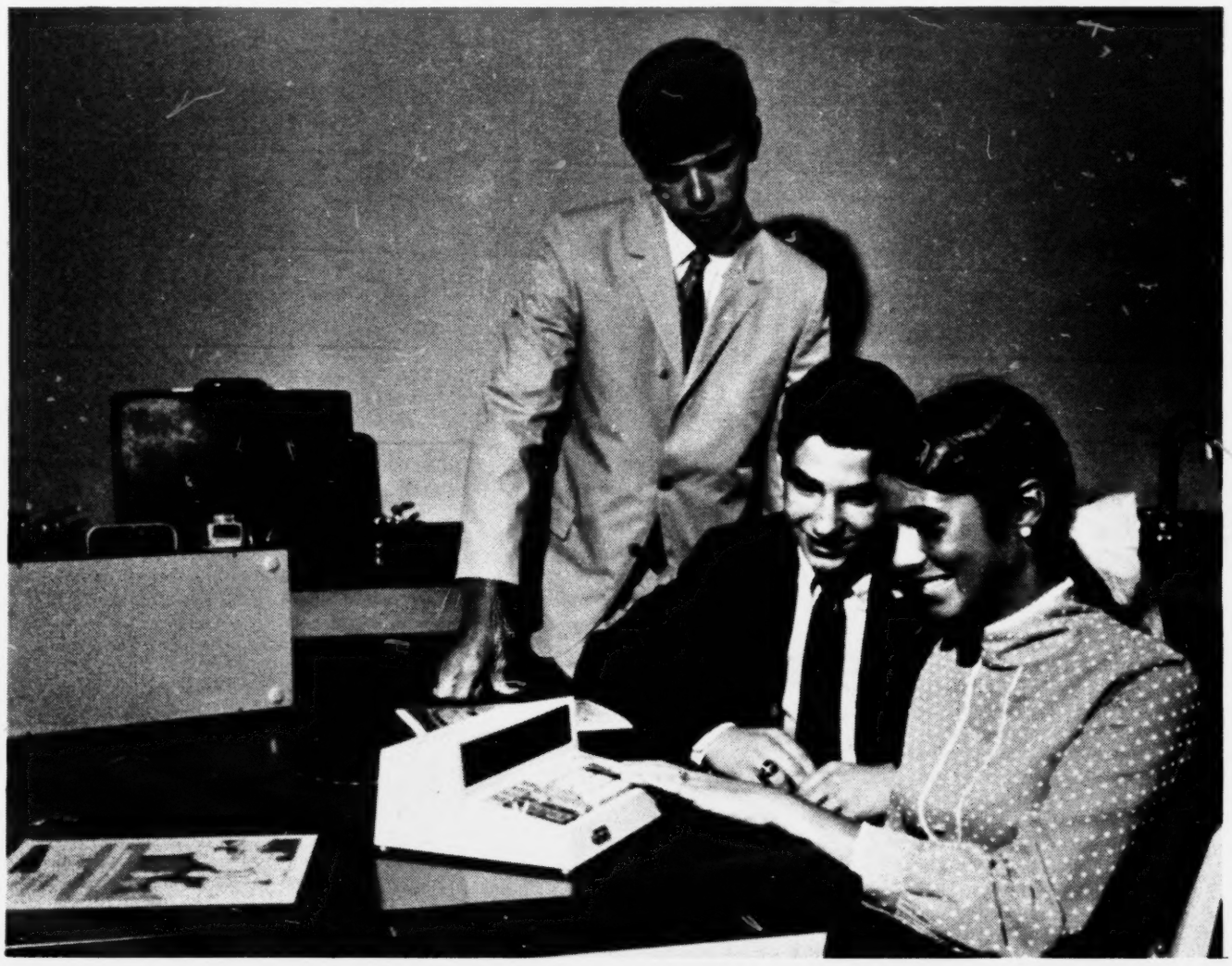
introduces

UTILIZING an ELECTRONIC CALCULATOR

A MANUAL for PLANNING and DEVELOPMENT



JANUARY 1970

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I

INTRODUCTION

This manual is based on the experiences gained from an experimental project utilizing an electronic calculator to facilitate instruction in mathematics in the 11th and 12th grades. The experimental project, conducted during the 1968-69 school year, was prompted by the need to devise solutions to a multi-faceted problem confronting today's educators.

On the one side, technological advances in industry are providing highly complex hardware for use as aids to instruction in the schools. On another, there is increasing pressure for individualizing instruction in a mass-education environment. On still another side, educators are faced with the problem of preparing students mathematically for concepts and employment opportunities which are as yet unconceived.

Faced with these problems, schools, and in particular school administrators, are often tempted to accept devices which seem to offer easy solutions. Specifically, in many instances, the school will buy "hardware" with little or no exploration into the availability of supportive "software."

In the present case, several Suffolk County school districts had expressed an interest in a particular item of "hardware", the Wang Laboratory Calculator. As a result, the Suffolk County Regional Education Center contracted with the New York State Education Department for approximately fifty per cent of the funds for an experimental project to be conducted at the Half Hollow Hills High School in Suffolk County. The Half Hollow Hills school district provided the remainder of the funds. A mathematics laboratory used in the experiment was equipped with 13 Wang series calculators, and the following questions were posed:

A. Statement of the Problem

1. Can electronic calculators be used in conjunction with classroom instruction to improve instruction in mathematics --- help to provide concept development, individualize instruction, provide for use by large numbers of students?

2. Can adequate "software" in the form of curriculum related materials be developed to make this tool valuable for students in eleventh and twelfth grade mathematics classes?

3. Are there peripheral applications-both in "hardware" and "software"--to assist in the teaching of chemistry, physics, and other subject areas?

In an attempt to answer these problems, the following hypotheses were formulated:

B. Hypotheses

1. The use of the calculator as an instructional tool will result in significantly greater achievement, by the experimental group, on standard or standardized tests in eleventh and twelfth grade mathematics.

2. The use of the calculator by the experimental group shall have a positive effect on student motivation.

3. Students in the experimental group will study a greater number of topics in the syllabus for Mathematics 11 and 12.

C. Procedures Utilized in the Experiment

1. Subjects involved in the investigation.

One hundred sixty one students in the experimental group were selected from Half Hollow Hills High School, a large school district in Suffolk County, which expressed interest in the program. The experimental group consisted of three Mathematics 11 classes, one Mathematics 11 accelerated, one Mathematics 12, and one Mathematics 12 accelerated. Each of these six classes was taught at a different period during the school day, thus avoiding any possible conflict of having two teachers wanting to attend the laboratory at the same time.

East Islip High School, another school in the county, similar in size, similar type of school population, same type of academic program, provided one hundred forty seven students for the control group. The control group consisted of four Mathematics 11, one Mathematics 11 accelerated, one Mathematics 12, and one Mathematics 12 accelerated.

2. Educational treatment.
   a) Individual grades of the 1968 mathematics Regents and Otis I.Q. scores were collected and analyzed.
   b) The mathematical section of the Cooperative Sequential' Test of Educational Progress was used for both pre and post-testing.
   c) Both groups filled out the Strong Vocational Interest Blank (Men-Women revised).
   d) In the experimental group, when the classroom teacher began a new unit which lent itself to reinforcement or

enrichment by supplementary use of the calculator, he brought his class to the laboratory where the students would "double up" using the calculators to find solutions to problems similar to their classroom work and homework problems. Many times the laboratory supervisor would conduct a short lesson to review or introduce new topics. For the remainder of the period he would assist individual students using the calculator to solve problems from teacher-prepared work sheets.

The mathematics laboratory was open seven periods a day for students to visit during study halls and lunch periods. In addition it was open after school for a minimum of one hour.

Classroom teachers of mathematics had observed that the magnitude or complexity of arithmetic and algebraic operations frequently hampered the students' conceptual development. Particularly illustrative of this are problems whose solutions involve the use of logarithms. Students become so immersed in the manipulation of the numerals involved that they lose sight of the underlying concepts and proceed in an automatic or noncomprehending manner.

With the calculators, teachers were able to instruct the students in three distinct ways, namely - manual classroom instruction, step by step machine solution of the problem, and programming a card for instantaneous solution of the problem.

3. Instruments used

a) 1968 New York State mathematics Regents results
b) IQ -- Otis Quick Scoring Test of Mental Ability
c) Cooperative Sequential Tests of Educational Progress
d) Strong Vocational Interest Blank (Men-Women Revised)

4. Technical description of procedures used for data analysis

An analysis of the variance of the means were performed, using the "t" test to determine significant differences.

D. Results of the Experiment

1. Pretests

A "t" test of the significance of the difference between the means indicated no difference at the .05 level in regard to

a) The means of the 1968 Mathematics Regents results
b) The means of the Otis I.Q. scores
c) The means of the pretesting results of the Sequential Test of Educational Progress.

2. Posttests

There was a significant difference between the means at the .01 level of the posttest results of the Sequential Test of Educational Progress. (NOTE: The control group was given the pre-Sequential Test of Educational Progress (STEP) during one 70 minute session, all students took the test at the same time. The same procedure was used for the posttesting. The experimental group took part I of the STEP test during a regularly assigned mathematics period on one day and then Part II was given on the following day. This procedure was used for both pre and posttesting. Although both groups used different procedures any possible contamination was present for both pre and posttest results).

Students in Mathematics 11 and 12 did not study a greater number of topics, they concentrated on reinforcing the required topics. Students in the accelerated Mathematics 12 course did study a greater number of topics. There are no results regarding student motivation which was to be tested at the end of the second year, as outlined in the original proposal.

The Half Hollow Hills school district viewed the results of the first year significant enough to warrant the adoption of the project on an operating basis. Thus, the experiment has concluded in the formal sense, and the calculators are being used in the regular high school program. All costs have been assumed by the school district.

II
REQUIREMENTS for IMPLEMENTATION

This section will present the approach taken by the Half Hollow Hills High School in the implementation of the project. It is by no means the only approach available to interested educators. The choice of personnel to be involved, facilities to be used, equipment and materials to be adopted will be a result of the planning efforts of an individual school or school district.

Planning

Adequate planning should precede the adoption of any innovative instructional approach no matter how optimistic the results of research. This is true in the present case, not only because of the expenditure of funds for equipment, but more critically, because of the expenditure of time on the part of teachers and students in the instructional process.

Planning activities may start with any member of the educational community - a building principal, superintendent, teacher, school board member, or member of the community. In your case, planning may begin with you, the reader.

The following is a suggested list of activities that a classroom teacher could follow to introduce the concept of a mathematics laboratory at the high school level.

1. Meeting with the school principal to discuss the feasibility of establishing a mathematics laboratory in the school. During this meeting the following areas could be discussed.

   a) why there is a need for a change
   b) what are the objectives
   c) how will these objectives be evaluated
   d) equipment and cost of the laboratory
   e) personnel to be involved
   f) students to be involved
   g) tentative procedure to be used
   h) future meetings

2. Meeting with the superintendent and high school principal to discuss, explain, and make notes of any suggestions.

After these two information meetings, a planning committee would be formed. The planning committee should consist of a coordinator and those interested members of the faculty who show concern for establishing a mathematics laboratory. Provisions should be made

to include all teachers in the mathematics department so that they may have a part in the group planning. Studies show that planning groups should not be too large, possibly five or six members however it is important that teachers feel that they are involved in the planning. The five or six members on the planning committee should solicit suggestions and invite others to planning meetings.

The planning committee should:

a) determine the objectives, and prepare a list of specific behavioral objectives
b) determine how these objectives will be evaluated
c) prepare a course of study
d) prepare a list of the best practices in effect locally and elsewhere (this necessitates research)
e) determine which equipment is best suited to their objectives and list the cost of this equipment including different configurations and cost
f) determine the best procedures to be used
g) provide for changes to take place (bi-weekly meetings of those teachers involved can be established to act as a clearinghouse for any problems that may occur).

In addition to the activities of the planning committee, the central office should supply adequate resources in the form of reference books, meeting rooms, secretarial help, supplies and materials.

Curriculum revision should be continuous. Many means of curriculum improvement could be used including, workshops, in-service, action research, surveys and clinics.

B. Personnel

Laboratory Supervisor: He should be an experienced mathematics teacher, trained in the use of the calculator, assigned full-time to the mathematics laboratory and to the students who use it. This teacher will be instrumental in the development of curricular materials for use with the calculator. He consults with central office staff, the building principal and teachers to help solve administrative operational problems. He should develop the content and procedures for in-service teacher training.

Building Principal: He must be available for the selection of participating teachers and for consultation with the laboratory supervisor in setting up scheduling and allocating space and equipment.

Teachers: Aside from an obvious professional interest in improving one's teaching, the teacher's chief asset will be his availability. He should be a member of the planning committee and available

to attend bi-weekly meetings. The committee acts as a clearing house for any problems that may occur. The teacher should work with the laboratory supervisor in providing a program of experience with the calculator in accordance with the curriculum and materials developed by the planning committee. He should become proficient in operating the calculator.

Secretary: Secretarial services should be provided for the typing of curriculum and related materials developed by the planning committee.

C. Equipment and Sources

The equipment utilized at Half Hollow Hills High School is from Wang Laboratories, Inc., 836 North Street, Tewksbury, Massachusetts 01876. However, equipment from other companies should also be investigated in the development of a laboratory.

The mathematics laboratory at Half Hollow Hills High School was originally equipped with:

3	Model 320K* Keyboards @ $470.	$1,410.00
9	Model 320KT Keyboards @ $920.	8,280.00
1	Model 360K Keyboard @ $500.	500.00
3	Model 320SE Electronic Package @ $3,250.	9,750.00
1	Model 360E Electronic Package @ $1,995.	1,995.00
1	Model CP-1 Card Programmer @ $800.	800.00
		$22,735.00

Rental terms: 2.8% per month of the total purchase price for 1 year including purchase option, service included

TOTAL $ 7,638.96

*K = Keyboard
KT = Keyboard Trigonometric
SE = Simultaneous Electronic Package

However, as a result of the first year's experience, equipment changes are being made. It is felt that the additional cost of trigonometric keyboards limited the number of CP-1 card programmers available for student use. Programs can be written to generate trigonometric tables, using the less expensive 320 keyboard coupled with a card reader.

The following configuration will give the laboratory more versatility at less cost:

12	Model 320K Keyboards @ $470.	$5,640.00
3	Model 320SE Electronic Packages @ $3,250.	9,750.00
1	Model 370 Programming Keyboard	1,200.00
1	Model 362E Electronic Package	2,295.00
1	Model CP2M Card Programmer, Master	800.00
1	Model CP2S Card Programmer, Slave	600.00
2	Model 371 Card Programmer @ $600.00	1,200.00
		$21,485.00
1	Model 301 Column Printer	750.00
	(Six months lease from date of delivery)	126.00

Rental terms: 2.8% per month of the total purchase price for 1 year including purchase option, service included

TOTAL $7,344.96

D. Materials and Sources

Reports concerning Computer Assisted Instruction constantly refer to "problems in software development". This can only be repeated in regard to calculator instruction, with an emphasis on the lack of available software materials.

At the present time pedagogical software appears to be non-existent. Attempts have been made to provide curriculum materials. This is usually in the form of "how to" solve specific mathematical problems. Individual companies have books (program libraries) which contain written programs that have been used to solve selected problems.

Many of the topics and materials used in Computer activities can be adapted for calculator activities.

Since there is no coordinating agency to provide a source of materials, the procurement of materials becomes a problem. The following suggestions attempt to give the reader a start in acquiring materials:

1. Contact established mathematics laboratories. (Individual companies can provide a list of schools using their equipment. Professional journals and newspaper articles refer to mathematics activities).
2. Become familiar with ERIC and ENTELEK publications.
3. State publications, such as, The New York State Education Department Division of Research publication, "Experimental and Innovative Programs", should be reviewed.

4. Local University personnel, Boards of Cooperative Educational Services and Regional Centers may provide names of people to contact.

Aside from content materials to be used with the calculators, certain user materials are necessary. The calculator companies usually provide program cards, program pads, large photographic displays of the keyboards, and workbooks where applicable. In addition, professional books and clerical supplies should be considered for curriculum development. If research is to be conducted during the program, standardized tests and interest blanks must be taken into consideration.

E. Facilities and Space

It is suggested that a separate room be equipped as a mathematics laboratory. Preferably, this room will be near the rooms or area in which mathematics instruction takes place.

The laboratory should be equipped with flat top tables, similar to desk tops found in science laboratories or cafeterias. It should also have movable chairs that may be grouped around the tables. Electrical outlets should be conveniently placed to avoid problems created by extension cords.

Calculators vary in size. The Wang calculators are 4½ inches in height, 10¼ inches in width, and 8 inches in depth. Table top space should be provided to connect a card programmer (5½ inches in height, 2½ inches in width, 9½ inches in depth) and allow sufficient writing space for each person operating the calculator.

III

INSERVICE TEACHER TRAINING

An important aspect of the electronic calculator program is the training of teachers who will be involved in the program. The following section outlines one course which can be utilized in an inservice setting, and presents sample materials to be used in such a course.

A. Course Outline

Lesson One

Introduction

A. Definition of terms
   1) calculator vs. computer
   2) keyboard
   3) card reader
   4) electronic package

B. Assembly of components
   1) caution-power switch off
   2) card reader between keyboard and electronic package

C. Keyboard Operations
   1) special switches
   2) explanation of keys

D. Machine Operations
   1) initial preparation
   2) clear display
   3) addition and subtraction
      a) Left and right adders
      b) adding contents of one register to another
      c) adding negative numbers
      d) position of decimal
   4) Multiplication
      a) function of the ENTER key
      b) function of the X= key
      c) "saving" answers
      d) product register
      e) chain multiplication
      f) combined operations
   5) Division
      a) function of Enter key
      b) function of ÷ =key
      c) inverse of multiplication
   6) Calculations (combined operations)
   7) Overflow (flashing light)

Lesson Two

Review of rational operations (addition, subtraction, multiplication, division), problem-solving (give sample problems)

Special Switches

A. Product Accumulator (give sample problems)

B. Entry Accumulator (give sample problems)

C. Multiplier Accumulator (give sample problems)

D. Using all switches at the same time (give sample problems)

Machine Operations

A. logarithms and antilogarithms
   1) natural logarithms
   2) exponential form
   3) function of $\log_e x$ key
   4) function of e^x key
B. Finding products with logarithms (use of addition registers)
C. Finding quotients with logarithms (use of addition registers)
D. Finding powers and roots using logarithms (use of product register)
E. Log logs
F. Changing to base 10

Problem-Solving

A. Quadratic equation
B. Series
C. Interest
D. Determinants
E. Remainder theorem

Lesson Three

Review of machine operations

Calculations of problems, involving combined operations of addition, subtraction, multiplication, division and nth roots.

Program

A. Definition

1) program
   a) set of instructions
   b) data
2) programming
3) programmer

B. Communication
   1) machine language (code)
   2) execution of instructions in prescribed sequence

C. Materials
   1) card
   2) port-a-punch and stylus
   3) program pad
      a) step number
      b) command
      c) code
      d) comment
      e) list of operations

   4) card reader
      a) start
      b) continue
      c) automatic switch
      d) step switch

Problem planning

A. Definition of problem
   1) alternate methods of solution
   2) range of data and answers

B. Solution of Problem manually

C. Type of Problem
   1) specific calculation for only one set of values
   2) repetitive

Fundamentals of Programming

A. Order of operations

B. Input-output
   1) start button
   2) continue button
   3) display window

C. Techniques
   1) prepared dittoed sheets with written programs on them shall be passed out and each step explained.
   2) debugging (step switch on card reader)
   3) altering card

Specific Problems to be programmed

A. Formulas
B. Formulating tables
C. Solution to system of Equations
D. Series
E. Vectors
F. Matricies
G. Determinants
H. Iteration (Newton's square root method)
I. Algorithms
J. Approximation formulas
K. Elements of Differentiation
L. Numerical integration
M. Modular Arithmetic
N. Probability
O. Statistical application
P. Assignment-write a program to:
   1) plot a graph
   2) evaluate a formula

Lesson Four

Review

Write a program to find f (x) for integral values of x from $-4 = x = 4$. Given f (x) $= x^2 - x - 6$

Laboratory Session

A. Independent work writing programs to
   1) evaluate formulas
   2) graph polynomials
   3) solve selected problems

B. Debugging (step switch on card reader)

Introduction to model 370

A. computer
   1) definition
   2) decision making

B. Similarity to model 320

C. Flow diagrams (symbols)

D. Program terminology
   1) Prime
   2) Mark
   3) Search
   4) Branch
   5) Loop
   6) Subroutine
   7) Verify program

E. Coding
   1) similarity to model 320
   2) additional commands
      a) search
      b) search and return
      c) skip if +
      d) skip if overflow
      e) skip if 0
      f) verify program

Assignment--write a program containing
   a) loop
   b) branch
   c) subroutine

Lesson Five

Review

A. Write the flow diagram and the program to increment the value of x by 1 until e^x will cause an overflow. Start with x=5

B. Review homework assignment

Debugging

A. Types of errors
   1) incorrect punching of cards
   2) incorrect logic on part of programmer

B. Special keys and switches
   a) Step key
   b) Display program key
   c) Display program switch
   d) Display work register switch
   e) Verify program key

Auxiliary Data Storage

A. 373 Data Storage register

1) Matrix
   a) column
   b) row
2) Store direct
   a) setting of toggle switches
   b) special operation key
   c) use of keyboard key with same program code command as the storage register
3) Recall direct
   a) setting toggle switches (special operations)
   b) use of keyboard key with same program code command as the storage register
4) Store indirect (automatic re-position of storage registers)
5) Recall indirect (automatic re-position of storage registers)

Laboratory Session

Independent work on writing and running programs

B. Examples of Materials:

The following examples of materials can be used in an in-service training program. A picture of a typical electronic calculator keyboard is presented on page 31 of this manual to assist in understanding the operations involved.

Mathematics Laboratory	In-Service	Machine Operations

1. a) using the left addition register, find the sum of
   87.2 + 4.56 + 147 (Ans. 238.7)

   b) using the right addition register, find the sum of
   258 + 32.1 + 20.3 (Ans. 310.4)

   c) find the total of these two sums (Ans. 549.16)

2. a) using the left addition register, find the following sum:
   $\sqrt{784} + 92.1 - \sqrt{228.01}$ (Ans. 105)

   b) using the right addition register, combine the following:
   62.7 + (-8) (Ans. 54.7)

   c) subtract the smaller of these two numbers from the larger:
   (Ans. 50.3)

3. a) (Al.) subtract 572 from 987 (Ans. 415)

   b) (Ar.) subtract 9 from -12 (Ans. -21)

   c) add these two results (Ans. 394)

4. a) (Al.) multiply 58.7 by 63.19 (Ans. 3709.253)

   b) (Ar.) multiply (8) (4) (3) (6.4) (Ans. 614.4)

   c) multiply these two products together (Ans. 2278965.043)

5. a) (Al.) multiply 58.7 by .98 (Ans. 57.526)

   b) (Ar.) multiply 9.3 by 8.7 (Ans. 80.91)

   c) multiply these two results together (Ans. 4654.428660)

6. a) Divide 11805 by 787 (Ar.) (Ans. 15)

   b) (Ar.) Divide 12972 by -564 (Ans. -23)

   c) Divide the quotient found in part (a) by the quotient found in part (b). (Ans. -.6521739130)

Mathematics Laboratory In-Service Course Machine Operations

Note: any time we use one of the blue keys and we want to save our answer, we usually store the answer, which is shown in the display window, in one of our addition registers. (this is done by pressing + Ar. or +Al., then we can recall our answer by pressing the recall button)

REVIEW:

1. a) Al. Find the sum of 7.2 + 9 -3.7 Ans. 12.5
   b) Ar. Combine: 62 - 9.8 + 13.5
   c) Subtract the smaller of these two numbers from the larger. Ans. 53.2

2. a) Al. Multiply $\sqrt{10}$ by 12 Ans. 37.94733192
   b) Ar. Divide 173 by 17.2 Ans. 10.05813953
   c) Multiply these two answers together Ans. 381.6795592

3. $\sqrt{\sqrt{\frac{576}{2} + (2187)(729)(27) - 12}}$ Ans. 3

4. Using the product accumulator find $\sqrt{8^2 + 7(9.2) + (13.5)^2}$
   Ans. 17.6252659

5. Using the product accumulator find 3.1(7.3) + 8(9.2) + 7(8.3)
   Ans. 154.33

6. Obtain total of invoice, total number of items, and then take a trade discount of 10% and a cash discount of 2% for paying invoice in 10 days. (Hint: taking a 10% discount off the invoice total is equivalent to multiplying invoice total by .90: then multiply result by .98 to obtain the total after a 2% cash discount.)

99@	$6.42
42@	3.17
62@	5.12
85@	3.55

Ans. total invoice $1387.91
total entries 288 items
after 10% discount $1249.119
after both discounts $1224.13662

7. Evaluate $7\frac{1}{3}$

Ans. 1.912931182

Mathematics Laboratory In-Service Programming

Last week, we considered writing a program to find the average of several numbers. We wanted to (a) find the number of grades we entered, (b) find the average.

We could find the average of 70, 94 and 86 by following these instructions

product accumulator and multiplier accumulator switches on
clear all
key 70
enter
key 1
X=
key 94
enter
key 1
X=
key 86
enter
key 1
X=
Rar.
Ral.
enter
Rar.
÷ =

OPERATING INSTRUCTIONS

1. Clear All
2. Prod. accum. and mult.accum.switches on
3. Index grade
4. Press start
5. Repeat steps 3 and 4 for all entries
6. press continue
7. press continue
8. read average

The above program can be written in the following manner

No.	Command	Code	Comment
00	Enter	41	entering the grade for multiplication
01	# 1	61	
02	X=	46	multiplying by one, this will accumulate our entries in the right addition register
03	stop	01	
04	Rar.	51	with the multiplier accumulator switch on we accumulate our
05	stop	01	entries in the right addition register, which we now read
06	Ral.	55	with the product accumulator switch on we are accumulating these products in the left register, which we now have

Continued:

No.	Command	Code	Comment
07	enter	41	
08	Rar.	51	
09	÷ =	47	We have just divided our total sum (which was in + A1) by the
10	stop	01	total number of entries which was in + Ar.

NOTE: Everytime we press start, the machine goes immediately to the beginning of the card and performs the first three instructions, then stops until we either press the start button or the continue button.

After we enter each grade, we press start. After all the grades are entered, we press continue, which means the machine now performs step 04, then stops(this shows us our number of entries) by pressing continue again, it performs steps 06 thru 10 (our averages).

Mathematics Laboratory In-Service Programming

Objective: To write a program to find any value of f (x) if f (x)= x^2+3x

No.	Command	Code	Comment
00	x^2	45	
01	+A1	56	stores the quantity x^2 so that we can add 3x to it
02	Constant #3	63	
03	Enter	41	preparing the number 3 for multiplication
04	stop	01	we stopped the machine to index x
05	x=	46	multiplying 3 times x
06	+ A1	56	adding this 3x to x^2
07	stop	01	read ans.

Operating Instructions:
1. Clear All
2. Index x
3. Press Start
4. Index x
5. press continue
6. read answer

The above program can be improved: a) We do not want to stop the machine to index x everytime we come to a new term. For example, if we had the following equation, $f(x) = x^5 + 3x^4 + x^3 - 7x^2 + 8x - 24$ and we used the above approach we would have to stop the machine four times to index (x); namely, when we got to $3x^4$, x^3, $-7x^2$, and 8x. We can avoid this by storing the variable in + Ar. in the beginning, then any time we need to index the variable we have the machine index the variable by giving the command Rar. which is code 51.
b) In the above program, we must start by clearing all, we can have the machine do this for us by starting our program with the command Car., Cal., which means clear adder right and clear adder left. This is done with code 50 and 54.

Objective: to rewrite the above program so that all we need do is to index (x), press start and read answer.

Continued:

No.	Command	Code	Comment
00	Clear adder left	50	
01	Clear adder right	54	
02	+Ar	52	We are now storing our variable in the right addition register, we will recall this later.
03	x^2	45	
04	+Al	56	
05	Constant #3	63	
06	Enter	41	
07	Recall adder right	51	Now, instead of stopping the machine to index (x), all we need do is recall right adder
08	X=	46	
09	+Al	56	
10	Stop	01	

OPERATING INSTRUCTIONS:

1. index (x)
2. press start
3. read answer

IV
CALCULATOR ASSISTED MATHEMATICS PROGRAM

A. Curriculum Outline

When the classroom teacher began a new unit which lent itself to reinforcement or enrichment by supplementary use of the calculator, he brought his class to the laboratory where the students, using the calculator, would find solutions to problems similiar to their classroom work and homework problems. As a result, curriculum was developed for the following areas:

Fundamental Operations

a) addition and subtraction
b) multiplication and division
c) involution and evolution

Complex Numbers
Determinants
Trigonometry of Right Triangle
Remainder Theorem
Theory of Equations
Rate of Change
Logarithms
Radian Measure
Angular Velocity
Inverse Trigonometric Functions
Relations and Functions
Analytic Geometry
Series
The constant "e"
Exponential Functions
Probability, Permutation, Combination
Integral
Euclidian Algorithm
Trigonometric Curves
Solution of Oblique Triangles
Integers mod p
Approximation Formulas
Quadratic Equations

B. Suggestions for Teaching Curriculum Material

When preparing lesson plans for a given topic, it is advisable to write down the specific objectives the teacher has in mind. Although most teachers have no trouble in stating their objectives verbally, it will be better to write them down on paper, preferably in terms of specific behavioral objectives, (see Robert F. Mager, Preparing Instructional Objectives, Fearon Publishers, Inc., 2165 Park Boulevard, Palo Alto, California 94306, 1962.).

The first year's experience has shown that the students will make use of the calculators in several ways, namely;

1. working with pre-programmed materials (the teacher will write the programs to be used).

2. working out the solution to problems for only one set of values, the so-called"one-shot" problems.

3. working with his own prepared programs to assist him to evaluate formulas, analyze patterns and plot functions.

Specific student materials, in the form of pre-programmed cards, can be prepared to provide both individual learning experiences and reinforcement. The student can input data, then read the answer. He will then be expected to find a relationship between his input and answer. Example: Given several equations of the form $ax^2+bx+c=0$, the student will input a, b and c and the machine will do the necessary calculations (the teacher has already programmed the calculator), and display the sum of the roots in the display window. The student can form a table to represent his input and output to assist him in finding the relationship between the sum of the roots and the coefficients a and b.

The student should be encouraged to write the formulas, equations or logarithmic form that he is using to solve a particular problem. Many times, the student attempts to solve the entire problem on the machine without any written guidelines.

Once the student is proficient in machine operations, it can be suggested that it is not necessary that he does all the calculations on the machine, some are still done mentally. Example, when calculating $6 + \sqrt{49} - \sqrt{7}$, some 11th and 12th grade students will use the machine to add 6 and $\sqrt{49}$. It

could be pointed out that it is much easier to do that part mentally and proceed to use the machine to evaluate $13 - \sqrt{7}$.

Emphasis should be placed upon the student's ability to write programs. While writing programs, the student becomes aware of the versatility, efficiency, performance, and limitations of the calculators. He develops his own algorithms. The student can develop programs that will relieve him of any tedious calculations involved in the solution of his problem. Thus, he can concentrate on concept development and interpretation of his results.

In general, it is suggested that the teacher use the inductive, empirical approach to the solution of problems. This is a departure from the approach of some teachers who give the student a formula, derive it and then show the students how to use it.

The teacher may find it helpful to keep a file on hand consisting of programs that are used often, such as programs that have been written to evaluate standard formulas. The student should be encouraged to prepare a file of his own.

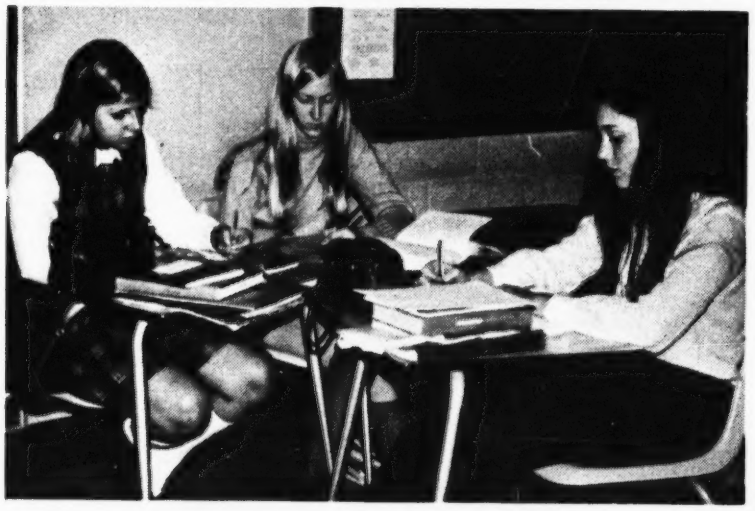
Finally, students will often come to the laboratory and ask if there are any problems that they can solve on the calculator, usually straight-forward calculations. It would be helpful to have a file of such problems of varying difficulty available.

C. A Pictorial Description of the Use of Electronic Calculators

There are many approaches to the use of the calculator that can be employed by a school in its mathematics program. The following is a pictorial description of one procedure for the use of calculators in a mathematics laboratory.

The classroom teacher can first provide instruction to his class in the regular classroom setting. This can incorporate small group, large group, and individualized techniques.

Large group session



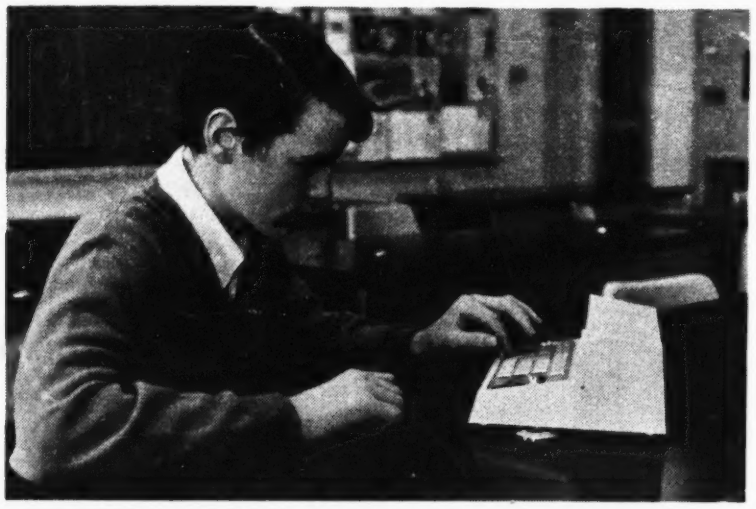
Small group session

When it is determined that use of the calculator can enhance the learning process, the teacher brings his class to the mathematics laboratory. At this time, the laboratory supervisor working with the classroom teacher, can provide the students with instruction on calculator applications to the particular mathematics unit under study. This can be in the form of a review of the calculator capabilities or an introduction to new calculator applications. Students can be supplied with teacher-prepared worksheets composed of problems to be solved on the calculator. With individualized assistance from the classroom teacher and the mathematics supervisor, students can then begin to solve these problems on their own.

Instruction in Math Lab

Work on Related Problems

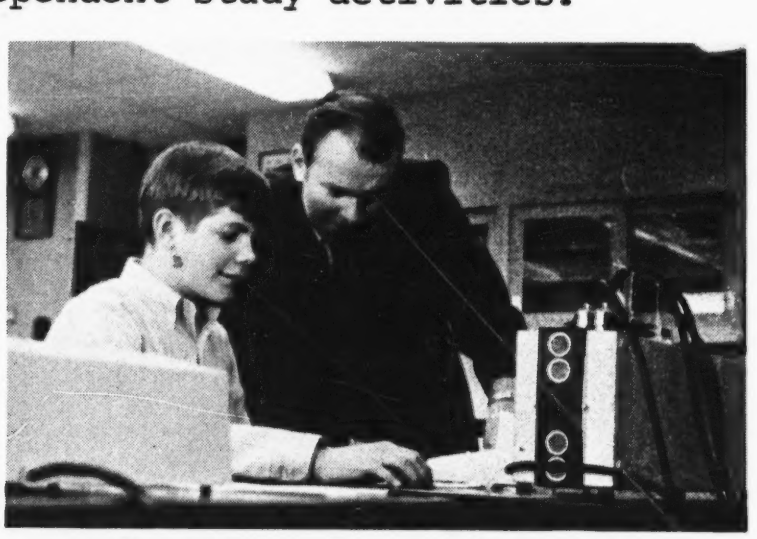
The process does not have to end at this point. Additional problems on work sheets can be given to the student by his teacher. Students can visit the laboratory during free periods or after school to work on these problems individually.



Individual Problem-Solving

Also, the laboratory supervisor can establish a file of enrichment problems related to all units in the various mathematics courses of study. Students can use these problems for independent study when they are motivated to do so. The laboratory supervisor should be available to assist students when they are working on these independent study activities.

Student Receives Problems for Independent Study.



Laboratory Supervisor Assists Student in Independent Study.

The procedures discussed above are presented as examples and are not necessarily the most effective. Procedures will be determined by individual teachers and administrators and will vary from school to school. In addition, the mathematics program need not be the only area for calculator use (see Section F for peripheral applications).

D. Instructional Objectives in Behavioral Terms

The following is a list of instructional objectives in behavioral terms. It is by no means, complete but is offered as an example.

Basic Objective:

The fundamental operations of addition, subtraction, involution and evolution shall be performed within thirty seconds to ninety-five percent accuracy.

(In each of the following, it is assumed the machine has been cleared of any previous operations).

1. The student will demonstrate his ability to add a set of five positive three digit numbers by indexing each number and pressing "+ adder right".

2. The student will demonstrate his ability to find the difference between two numbers by indexing the minuend and pressing "+ adder right" and then index the subtrahend and press "-adder right".

3. The student will demonstrate his ability to multiply two numbers by indexing the first factor and pressing "Enter" then he will index the second factor and press "x=".

4. The student will demonstrate his ability to square a number by indexing the number and pressing "x^2".

5. The student will demonstrate his ability to find the square root of a number by indexing the number and pressing "$\sqrt{\ x\ }$".

6. Given the rectangular form of a complex number a+bi (where $a \geq o$ and $b \geq o$) the student will write a program to convert this complex number to polar form r Cis θ.

7. Given a 2 x 2 matrix, the student will find the determinant by calculating the difference between the principal diagonal and the secondary diagonal.

8. The student will evaluate the determinant $\begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix}$ as outlined in #7 and compare it to $\begin{vmatrix} a_1 & a_2 \\ b_1 & b_2 \end{vmatrix}$ when rows are changed into columns and columns into rows. (three different examples)

9. The student will demonstrate his ability to find the sine or cosine of any acute angle by indexing the angle and pressing either "Sin" or "Cos".

10. Given a positive number, the student will demonstrate his ability to find arc tan by indexing the number and pressing "tan $^{-1}$".

11. Given a positive number within the range of the sine function, the student will demonstrate his ability to find arc sin by indexing the number and pressing "Sin^{-1}".

12. Given an equation f(x), the student will demonstrate his ability to find f (a) by evaluating the original function substituting "a" for x.

13. Given an equation f(x), the student will demonstrate his skill in writing a program that will find any f(a).

14. The student will apply the concept of the remainder theorem in determining if (x-a) is a factor of f(x) by evaluating f(a).

15. The student will demonstrate his skill in writing a program that will find the remainder upon dividing f(x) by (x-a).

16. With the use of the calculator, the student will construct a table of ordered pairs (a,f(a)) to assist him in graphing f(x).

17. Given an equation, all of whose coefficients are integers, the student will write the possible candidates for a solution applying the concept that if c/s is a rational fractional root of the equation, then c is a factor of the constant term and d is a factor of the leading coefficient.

18. The student will demonstrate his ability to find the natural logarithm of any positive number less than 10 digits, by indexing the number and pressing "$\log_e$ x".

19. The student will apply previous learned concepts to demonstrate his ability to find the logarithm of a positive number to any positive base n (n not equal to 1).

20. The student will calculate $\log_b N=a$ and compare this with a $\ln b=N$.

21. When given a problem involving powers, roots, and products and quotients, the student will demonstrate his skill in rewriting the problem in logarithmetric form.

22. When the logarithm of a number to the base "e" is given, the student will demonstrate his ability to find the antilogarithm by indexing the number and pressing "e^x".

23. The student will write a program to find the nth root of any positive number by using logarithms.

24. The student will write a program to find the common logarithm of any positive number less than 10 digits.

25. If a sequence of positive numbers forms a geometric progression, the student will verify that the logarithms of these numbers to a given base form an arithmetic progression by calculating the difference between the logarithms and applying the concepts of arithmetic progressions.

26. Given that y is a function of x and y changes from y_1 to y_2 as x changes from x_1 to x_2, the student will demonstrate his ability to find the average rate of change by dividing the change in y by the change in x.

27. Given y=f(x), the student shall demonstrate his skill in writing a program that will give him the average rate of change between any two values x_1 and x_2 .

28. Given y=f(x), the student will write a program that will find the value of the first derivative for some given x.

29. Given d=f(t), the student will write a program to find the velocity and acceleration for some value of t.

30. The student will demonstrate his ability to find the number of degrees in one radian by dividing 180 by π ($\pi \approx 3.14159265$)

31. The student will demonstrate his skill in writing a program that will convert degrees to radians and vice versa.

32. Given x in radians, the student will demonstrate his ability to calculate the first 5 terms of the infinite sequence.

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \frac{x^6}{6!} + \frac{x^8}{8!} \quad \ldots.$$

33. The student will compare his results of #32 using a table of radians for cos x.

34. The student will demonstrate a skill in writing a program to determine the angular velocity of a moving particle.

35. The student will demonstrate his ability to find the value of "e" to 9 decimal places by indexing 1 and pressing "e^x".

36. The student will write a program, using logarithms to solve for A given the compound interest formula, where P=1 dollar, t=1 year and n is the only variable.

37. The student will use this program (336) to evaluate A if n is a) 1000 b) 5000 c) 10,000. He shall then verbally state his interpretation of this problem.

38. The student will calculate the $\lim_{n \to \infty} (1 + \frac{1}{n})^n$ and compare this with the value of "e."

39. Given the series $e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^n}{n!} + \ldots$
the student will calculate
the first 5 terms of this series when x=2 and compare this with e^x which he obtains by indexing 2 and pressing "e^x".

40. Given an equation $y=e^x$, the student will construct a table of values for (x, e^x) to assist him in plotting the graph of $y=e^x$.

41. The student will calculate $y=2^x$ and compare this with $y=e^{x \ln 2}$.

42. The student will apply concepts previously learned to demonstrate his skill in using the calculator to solve problems relating to probability, permutations, and combinations.

E. Examples of Curriculum Materials:

The following examples of materials are presented to illustrate the wide range of possible content area which can be covered while utilizing an electronic calculator. The programming materials pose no special problems for the students. Indeed, programming with the calculator seems to evoke student motivation. Of course, additional problems can be taken from most mathematics text books.

In order to assist the reader in understanding the calculator terminology, a picture of a calculator keyboard is presented below.

Calculator with keyboard display.

KEYBOARD OPERATIONS

CLEAR ALL	In starting a problem this key is pressed to clear the machine of previous calculations.
Display Window	The visual output for sign of number, the number, and decimal point.
CLEAR DISPLAY	Removes only the number from display.

ADDERS

(Independent of each other)

$+A_L$	is read "plus Adder left." Adds the number in display to the number in the adder on left. The sum is in display and the adder on left.
$-A_L$	is read "minus Adder Left." Subtracts the number in display from the number in the adder on left. The difference is in display and the adder on left.
RECALL ADDER Left	Brings to the display that number which is also in the adder on left.
CLEAR ADDER Left	Clears only the left adder of previous calculations.
$+A_R$	is read "plus Adder Right." Adds the number in display to the number in the adder on right. The sum is in display and the adder on right.
$-A_R$	is read "minus Adder Right." Subtracts the number in display from the number in the adder on right. The difference is in display and the adder on right.
RECALL ADDER Right	Brings to the display that number which is also in the adder on right.
CLEAR ADDER Right	Clears only the right adder of previous calculations.

CHANGE SIGN

Changes the sign of number in display.

PRODUCT STORAGE

ENTER

This key takes the number in the display and puts it in the Product Storage by pressing this key.

x=

is read "times equal". This key multiplies those numbers already in Product Storage by the number in display. Read product in display window.

÷ =

is read "divide equals." This key divides the number in display into those numbers already in the Product Storage. Read quotient in display window.

This key will also yield the reciprocal value of the number in display.

x^2

is read "x squared." Finds the square of the number in display.

This key will also multiply the square of a number by those numbers already in the Product Storage.

$\sqrt{x}$

is read "square root of x." Takes the square root of the number in display.

This key will also multiply the square root of a number by those numbers already in the Product Storage.

$Log_e x$

Finds the natural logarithm of the number in display.

e^x

Finds the anti-logarithm (exponential) of the number in display.

SPECIAL SWITCHES

PROD ACCUM

(Product Accumulator) This switch automatically adds products, quotients, squares, and square roots in the adder on left.

MULT ACCUM

(multiplier accumulator) This switch automatically adds in the adder on the right those numbers in display which are followed by the x=, ÷=, x^2 and $\sqrt{x}$ keys.

ENTRY ACCUM

(entry accumulator) This switch automatically adds in the adder on right those numbers in display followed by the ENTER key

Mathematics Laboratory Machine Operations

Adder Right (Ar.) Adder Left (Al.)

1.a) Using left addition register, find the sum of 1.23 + 45.6 +789. (835.83)

b) Using right addition register find the sum of 9.87 +65.4 321. (396.27)

c) Find the total of these two sums. (1232.1)

2.a) Add in left register (Al.)
74.1 + (-8.52) + (.0369) ans. (65.6169)

b) Add in right register (Ar.)
951 + (-753) + 2 ans. (200)

c) Find the sum of these two numbers ans. (265.6169)

3.a) (Al) Subtract 587 from 962 ans. (375)

b) (Ar.) Subtract 962 from 1587 Ans. (625)

c) Find the sum of a + b Ans. (1000)

4.a) Subtract 1157 from 7511 and put answer in (Al.) Ans.(6354)

b) Subtract 8 from -10 Ans. (-18)

c) add these two results Ans. (6336)

5.a) (Al.) Subtract -726 from 342 Ans. (1068)

b) (Ar.) Subtract -76 from 32 Ans.(108)

c) Subtract the smaller of these two numbers from the larger.
Ans. (960)

6.a) (Al.) Subtract -84.7 from -92.1 Ans. (-7.4)

b) (Ar.) Subtract -92.1 from -84.7 Ans. (7.4)

c) Subtract the smaller of these two numbers from the larger
Ans. (14.8)

Mathematics Laboratory — Machine Operations

1. a) Multiply (48.7) (16) save this in A1. Ans. (779.2)

   b) Multiply (14.7) (-12) Ans.(-176.4)

   c) Subtract the smaller product from the larger. Ans. (955.6)

2. a) Multiply (36) (9) (47) (18) save this in A1. Ans. (274104)

   b) Multiply (176.2) (.034) Ans. (5.9908)

   c) Multiply these two products Ans. (1642102.234)

3. a) Divide 19 by 7.2 save this in A1. Ans.(2.638888889)

   b) Divide 127 by 4 Ans. (31.75)

   c) Divide the answer to part (a) by the quotient in (b)
   Ans. (.0831146107)

   d) Add the answer in part (c) to the answer in (b)
   Ans. (31.83311461)

4. a) Divide $\sqrt{3136}$ by 8 ans. (7) store this in A1.

   b) Divide 18 by $\sqrt{256}$ ans. (1.125) (NOTE: if you key 18 and enter and then key 256 and press $\sqrt{X}$ button, it takes 256 and multiplies this by 18)

   c) Subtract the smaller number from the larger and square your result. Ans. (34.51562500)

5. a) Find Sin 42^{o} Ans. (.6691306065)

   b) Find Csc 42^{o} Ans. (1.494476550)

6. a) Evaluate 3 Cos. 18^{o} Ans. (2.853169555)

   b) Find 1/3 Sec. 18^{o} Ans. (.3504874073)

   c) Find the product of (3 Cos. 18^{o}) (1/3 Sec. 18^{o})

7. $\sqrt{7^2 + 3^2 - 1^2}$ Ans. (6.480740698)

8. $$\frac{(47.2)\ (16.3)\ (.04)}{(12)\quad (3.7)}$$ Ans. (.6931171171)

Mathematics Laboratory

1. Find $\sqrt{78452.36}$ Ans. (280.0934844)

2. $(37.5769)^2$ Ans. (1412.023414)

3. a) Using the left addition register, find the sum of
.087 + 78.6 + 5678 Ans. (5756.687)

   b) Using the right addition register, find the sum of:
875 + (- 45.9) + 36.54 Ans. (865.64)

   c) Find the total of these two sums Ans. (6622.327)

4. Multiply 875 by 74.83 Ans. (65476.25)

5. Divide 876 by 3.14 Ans. (278.9808917)

6. a) multiply (756) (.17) save this in adder left. Ans. (128.52)

   b) multiply (15.4) (-63) save this in right adder. Ans. (-970.2)

   c) subtract the smaller product from the larger. Ans. (1098.72)

7. a) divide 104348 by 33215 Ans. (3.141592654) (do you recognize this number?)

8. a) divide $\sqrt{5467}$ by 8 save this in adder left Ans. (9.242395523)

   b) using the right addition register find $\sqrt{7654}$ -15.487
Ans. (72.00014191)

   c) find the product of these two answers. Ans. (665.4537892)

9. Evaluate $\sqrt{9^2 + (3.4)^2 - (6.1)^2}$ Ans. (7.439758061)

10. Evaluate $\dfrac{(47.2)\ (9.5)\ (16)}{(8.3)\ (-7.2)}$ Ans. (-120.0535475)

11. Evaluate $\sqrt[4]{43046721}$ Ans. (3)

12. Evaluate $\sqrt{\dfrac{3.492}{0.537} + (6.8)(73.9)(6) + (4.32)^2}$

Ans. (55.13878121)

Mathematics Laboratory

1) a. Using the left addition register find the sum of 47.2+183.78
Ans. (230.98)

b. Find the square root of the sum found in part (a)
Ans. (15.19802619)
(Since this sum is already in the display window we need only to push X button. NOTE: the sum of part a is saved in the left addition register and can be recalled by pushing recall adder left)

c. Using the right addition register find the sum of
123.45 + 678.9 Ans. (802.35)

d. Find the sum of (a) and (c) Ans. (1033.33) (We have the sum of (a)in the left addition register, the sum of (c) is in the right addition register, at this step it is also in the display window, hence by pushing +adder left it will take the number in the display window (802.35) and add it to the number in the left addition register which is 230.98)

2) a. Multiply (68) (93) Ans. (6324) (key 68, Enter(it is now entered into the product register) Key 93, push X=) NOTE: if we intended to use this product we must save it in either of our two addition registers.

b. Multiply (53) (-72) Ans. (-3816) (use change sign button, after you key 72)

c. Find $\sqrt{(68)\ (93) + (53)\ (-72)}$ Ans. (50.07993610)

3) a. Find the reciprocal of 45 Ans. (.02222222222)

b. Divide 82 by 3 Ans. (27.333333333333)

c. Find the product of (a) and (b) Ans. (.6074074067)

4) Use product accumulator switch

a. $\sqrt{643(73) + 42.53(23) + 62.5(1)}$ Ans.(219.04109)

b. $\sqrt{3^2 + 5^2 + 6^2}$ Ans. (8.3666026)

5) a. Find $\log_e 582.7$ Ans. (6.36767247)

b. Find $\sqrt[7]{9}$ Ans. (1.368738106)

6. $\sqrt{\dfrac{\sqrt[5]{(21.879)^3}}{29.1}}$ Ans. (.4678016465)

Mathematics Laboratory

Programming

+ AR ----------plus adder right
-AR ----------minus adder right
+AL ----------plus adder left
-AL ----------minus adder left
RAL ----------recall adder left
RAR ----------recall adder right
CAL ----------clear adder left
CAR----------elear adder right

1) $\left(\frac{ab + d}{c}\right)$

1. clear all
2. Key a
3. Enter
4. Key b
5. x=
6. +AL
7. key d
8. +AL
9. Enter
10. key c
11. ÷=
12. x^2

2) $\sqrt{\frac{a(b)^2 + e(d)^2}{bc + d}}$

1. clear all
2. key a
3. Enter
4. Key b
5. x^2
6. +AL
7. Key c
8. Enter
9. Key d
10. x^2
11. +AL
12. Key b
13. Enter
14. Key c
15. x=
16. +AR
17. Key d
18. +AR
19. RAL
20. Enter
21. RAR
22. ÷=
23. x

3) $\sqrt[b]{\frac{a(b)^2}{c}}$

1. Key a
2. log x
3. +AL
4. Key b
5. log x
6. Enter
7. Key 2
8. x=
9. +AL
10. key c
11. log x
12. -AL
13. Enter
14. Key b
15. ÷=
16. e^x

Write a program on the sheets provided, to evaluate the following problems.

1) $a^2(b) + \frac{3a}{b} - b^2$

2) $\frac{-b+\sqrt{b^2-4\ a\ c}}{2a}$

3) $\sqrt{\frac{s(s-a)(a-b)\ (s-c)}{\frac{a+b+c}{2}}}$

4) $\sqrt[5]{\frac{a\ (b)^2(c)^3}{d}}$

5) $\frac{a^2 + b^3 - c^{5/4}}{a}$

370 - 380 PROGRAM

No. Date:

No.	Cmd	Code	Comment	No.	Cmd	Code	Comment
00	CAR	50		40			
01	CAL	54		41			
02	x^2	45		42			
03	+AL	56		43			
04	stop	01	Index B	44			
05	x^2	45		45			
06	+AL	56		46			
07	$\sqrt{x}$	44		47			
08	+AR	52		48			
09	stop	01	Index C	49			
10	Enter	41		50			
11	RAR	51		51			
12	÷ =	47		52			
13	stop	01	Read answer	53			
14			absolute valu	54			
15				55			
16				56			
17				57			
18				58			
19				59			
20				60			
21				61			
22				62			
23				63			
24				64			
25				65			
26				66			
27				67			
28				68			
29				69			
30				70			
31				71			
32				72			
33				73			
34				74			
35				75			
36				76			
37				77			
38				78			
39				79			

Given: equation of a straight line in the form of

$Ax + By + c = 0$

$(A \neq 0)$

Find: The distant from the origin.

Equipment: 320

Operating Instructions

1. Index A press start
2. Index B press continue
3. Index C press continue
4. Read answer (take absolute value)

List of operations.

00		40	
01	Stop	41	Enter
02	Search	42	$\text{Log}_e x$
03	Search & Return	43	e^x
04	Return	44	$\sqrt{x}$
05	Skip if +	45	x^2
06	Continue	46	x =
07	Mark	47	+ =
	370-380 370-2-380-2		
10	Store 0 (Store HB)	50	Clear AR
11	Store 1 (Store HA)	51	Recall AR
12	Store 2 (Add Full)	52	+ AR
13	Store 3 (Store Full)	53	− AR
14	Recall 0 (Recall HB)	54	Clear AL
15	Recall 1 (Recall HA)	55	Recall AL
16	Recall 2 (Sub Full)	56	+ AL
17	Recall 3 (Recall Full)	57	− AL
20	Skip if Overflow	60	0
21	Control	61	1
22	Read 1	62	2
23	Read 2	63	3
24	Write 1	64	4
25	Write 2	65	5
26	Store Dir	66	6
27	Recall Dir	67	7
30	Skip if 0	70	8
31		71	9
32	Store Ind	72	
33	Recall Ind	73	
34		74	
35		75	
36	Group 1	76	Clear Display
37	Group 2	77	Change Sign

Wang Laboratories, Inc. 836 NORTH STREET TEWKSBURY, MASSACHUSETTS

370-330 PROGRAM No. Date:

No.	Cmd	Code	Comment	No.	Cmd	Code	Comment
00	CAR	50		40			
01	CAL	54		41			
02	SRo	10		42			
03	stop	01	Index r_2	43			
04	SR_1	11		44			
05	stop	01	Index r_3	45			
06	SR_2	12		46			
07	+AL	56		47			
08	RSR_1	15		48			
09	+AL	56		49			
10	RSRo	14		50			
11	+AL	56		51			
12	Chg.Sgn.	77		52			
13	stop	01	Coeff. x^2	53			
14	RSR_0	14		54			
15	Enter	41		55			
16	$+AR_1$	15		56			
17	x^2	46		57			
18	+AR	52		58			
19	RSR_1	15		59			
20	Enter	41		60			
21	RSR_2	16		61			
22	X=	46		62			
23	+AR	52		63			
24	RSR_1	15		64			
25	Enter	41		65			
26	RSR_2	16		66			
27	X=	46		67			
28	+AR	52		68			
29	stop	01	Coeff. x	69			
30	RSR_0	14		70			
31	Enter	41		71			
32	RSR_1	15		72			
33	Enter	41		73			
34	RSR_2	16		74			
35	X=	46		75			
36	Chg.Sgn.	77		76			
37	stop	01	constant	77			
38				78			
39				79			

Given: 3 real roots of a cubic equation

Find : The equation in the form

$$x^3 + \frac{b}{a}x^2 + \frac{c}{d}x + \frac{d}{a} = 0$$

Equipment: 360

Operating Instructions.

1. Index r_1 press start
2. Index r_2 - continue
3. Index r_3 - continue
4. read coeff. x^2-continue
5. read coeff. x-continue
6. read constant term

List of operations.

00			40		
01	Stop		41	Enter	
02	Search		42	$\log_e x$	
03	Search & Return		43	e^x	
04	Return		44	$\sqrt{x}$	
05	Skip if +		45	x^2	
06	Continue		46	X =	
07	Mark		47	+ =	
	370-380	370-2-380-2			
10	Store 0	(Store MB)	50	Clear AR	
11	Store 1	(Store MA)	51	Recall AR	
12	Store 2	(Add Full)	52	+ AR	
13	Store 3	(Store Full)	53	- AR	
14	Recall 0	(Recall MB)	54	Clear AL	
15	Recall 1	(Recall MA)	55	Recall AL	
16	Recall 2	(Sub Full)	56	+ AL	
17	Recall 3	(Recall Full)	57	- AL	
20	Skip if Overflow		60	0	
21	Control		61	1	
22	Read 1		62	2	
23	Read 2		63	3	
24	Write 1		64	4	
25	Write 2		65	5	
26	Store Dir		66	6	
27	Recall Dir		67	7	
30	Skip if 0		70	8	
31			71	9	
32	Store Ind		72		
33	Recall Ind		73		
34			74		
35			75		
36	Group 1		76	Clear Display	
37	Group 2		77	Change Sign	

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370 - 380 PROGRAM No. Date:

No.	Cmd	Code	Comment	No.	Cmd	Code	Comment
00	CAR	50		40			
01	CAL	54		41			
02	SR_0	10		42			
03	stop	01	Index k	43			
04	SR_1	11		44			
05	+AR	56		45			
06	stop	01	Index c	46			
07	SR_2	12		47			
08	- AL	57		48			
09	Enter	41		49			
10	#2	62		50			
11	X=	46		51			
12	÷ =	47		52			
13	stop	01	Read a	53			
14	CAL	54		54			
15	RSR_2	16		55			
16	+ AR	56		56			
17	x^2	45		57			
18	-AR	53		58			
19	RSR_1	15		59			
20	-AL	57		60			
21	RSR_1	15		61			
22	x^2	45		62			
23	+AR	52		63			
24	RSR_0	14		64			
25	Enter	41		65			
26	RAL	55		66			
27	÷ =	47		67			
28	stop	01	Read b	68			
29	RSR_0	14		69			
30	x^2	45		70			
31	+AR	52		71			
32	Enter	41		72			
33	RAL	55		73			
34	Ch.Sgn.	77		74			
35	÷ =	47		75			
36	Enter	41		76			
37	#2	62		77			
38	÷ =	47		78			
39	stop	01	read c	79			

Given: a point whose coordinates are (h,k) and the straight line $y = c$ $(c \neq k)$

Find: Equation of the locus of points equidistant from the point and the straight line, namely the parabola in the form of $ax^2 + bx + c$

Equipment: 360

Operating Instructions

1. Key h press start
2. Key k press continue
3. Key c press continue
4. read a press continue
5. read b press continue
6. read c

List of operations.

00			40		
01	Stop		41	Enter	
02	Search		42	$Log_e x$	
03	Search & Return		43	e^x	
04	Return		44	$\sqrt{x}$	
05	Skip if +		45	X^2	
06	Continue		46	X =	
07	Mark		47	÷ =	
	370-380	370-2-380-2			
10	Store 0	(Store HB)	50	Clear AR	
11	Store 1	(Store HA)	51	Recall AR	
12	Store 2	(Add Full)	52	+ AR	
13	Store 3	(Store Full)	53	- AR	
14	Recall 0	(Recall HB)	54	Clear AL	
15	Recall 1	(Recall HA)	55	Recall AL	
16	Recall 2	(Sub Full)	56	+ AL	
17	Recall 3	(Recall Full)	57	- AL	
20	Skip if Overflow		60	0	
21	Control		61	1	
22	Read 1		62	2	
23	Read 2		63	3	
24	Write 1		64	4	
25	Write 2		65	5	
26	Store Dir		66	6	
27	Recall Dir		67	7	
30	Skip if 0		70	8	
31			71	9	
32	Store Ind		72		
33	Recall Ind		73		
34			74		
35			75		
36	Group 1		76	Clear Display	
37	Group 2		77	Change Sign	

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F. Applications of the Calculator in Other Areas of the Curriculum:

In the area of mathematics, the uses of electronic calculators are quite evident. But what of other areas of the total curriculum? Are there applications of the calculator in the physical sciences, the social sciences, the arts and humanities?

The electronic calculator should be viewed as an aid to problem-solving. In the previous sections, the calculator was not put forth merely as a machine with which correct answers could be achieved or learner-calculated answers checked. Tedious, if not impossible, calculations could be achieved, allowing the learner to concentrate on problem-solving and concept formulation. This can be applied to subjects other than mathematics since one of the primary goals of all subject areas is the development of the ability to solve problems.

Business education students can solve problems that confront business and industry, as well as become familiar with equipment, such as calculators, that is used in business. This approach also affords students the opportunity to learn from local businessmen the kinds of problems with which they are faced. The students are then working with real-life problems and not hypothetical situations. An outstanding example of this type of activity is found in the Wynne, Arkansas Mathematics Laboratory Project. [1]

In social studies, complex problems that confront government leaders can be presented to students and approached realistically and completely. Local, state, national or international problems can be dealt with. Calculators can be used to answer questions and generate hypotheses related to data on population growth rates; racial, religious, and economic makeup of groups; environmental conditions; and other factors affecting our lives.

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[1]Bill Lewis, "Underachievers Measure Up," American Education, (February, 1969) pp. 27-28. Also see ERIC Microfiche No. ES000529.

The area of science presents a wide range of possible uses for calculator-assisted instruction. Complex formulas in chemistry and physics can be presented to students without fear of their not having sufficient time or capability to finish tedious calculations. Once again, emphasis can be placed on solving problems and understanding concepts. The space age will present untold scientific problems to be discussed in science classes. At this point, the Astronomy Club at Half Hollow Hills is using the mathematics laboratory calculators to solve many problems involving complex formulas.

Industrial Arts is another area in which creative educators may find applications for electronic calculators. The study of electricity, especially circuitry, is one aspect of industrial arts that is being explored with the calculator in mind.

Finally, the possible use of calculators should not be limited to the secondary level. Many of the same reasons for calculator use in the high school can be applied to the elementary school. The primary goal should be to assist students in the development of problem-solving ability. The calculator can provide assistance in the achievement of this goal as well as to serve to motivate students in many areas of the elementary school curriculum.

V
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The following are annotations of calculator projects and research studies:

CANADIAN PUBLIC SCHOOLS

A recent Canadian study investigated the hypothesis that use of calculators in mathematics classes will have a positive effect on student performance, and on their self-confidence and attitude towards mathematics. The study was designed to test calculators with two groups of ninth grade students and one group of fifth grade students. Experimental and control classes were set up for each group and one ninth grade group contained a class to control for the "Hawthorne effect." Teacher performance was a variable that the researchers also attempted to control.

There were no significant differences between experimental and control classes on the three dependent variables studied. The lower the I.Q. level of the group, the more teacher enthusiasm for the calculators was displayed. This was considered a function of the calculator's potential as a motivational "toy" for underachievers rather than increased pupil performance. At best, there was a feeling of increased productivity among students not previously capable of it, thus, easing classroom behavior problems.

See-R.R. Longstaff and others, "Desk Calculators in the Mathematics Classroom," a paper presented at the Canadian Conference on Educational Research, Canadian Council for Research in Education, Ottawa, Ontario (June, 1968), pp. 1-11. or
Research in Education V.4 No. 10 (October, 1969). ERIC microfiche No. ED029498.

COMPUTING MACHINES-HAND OPERATED

This was an experimental study consisting of twenty-five matched pairs. The students were matched on I.Q. and on reasoning and computation scores.

While there were no significant differences between the experimental and control groups on post-tests, the authors concluded that the calculators did help the students improve in reasoning and computation. In view of the absence of significant differences, the reader should be cautioned not to make major decisions as to calculators based on this research project.

See-Howard Fehr, George McMeen, and Max Sobel, "Using Hand-Operated Computing Machines in Learning Arithmetic," The Arithmetic Teacher, III (October, 1956), pp. 145-150.

LEVITTOWN (NEW YORK) PUBLIC SCHOOLS--"LABORATORY PROCESSES IN MATHEMATICS."

This was an experimental program funded by New York State Education Department's Bureau of School and Cultural Research. The project utilizes a laboratory environment for mathematical instruction designed to help structure the logical thinking of non-mathematically oriented students. The laboratory approach to mathematics instruction incorporates the use of calculators and flow-charting methods of problem-solving. The experiment was designed to measure hypothesized growth in computational skills, problem-solving, conceptual skills, and attitudinal changes.

For information contact-
Louis Pucci, Administrative Assistant to the Superintendent, Levittown Public Schools, Levittown, New York 11756. or Bureau of School and Cultural Research, University of the State of New York, The State Education Department, Albany, New York 12224.

NEW YORK STATE PUBLIC SCHOOLS

A survey of public secondary schools was conducted by the Bureau of Mathematics Education, New York State Education Department in 1967-1968. The data indicated that a small percentage (13 per cent) of the total number of public secondary schools that responded (1022) had desk

calculators available for mathematics department use. In addition, the survey yielded data relating to the number of calculators in use which have computer features. The use of these calculators indicate that pupils can be involved in a high level of problem analysis and flow-charting. The data showed that twenty-five schools or approximately two per cent of the respondents had calculators with computer features in their mathematics departments.

See-Aaron L. Buchman, "The Use of Calculators and Computers in Mathematics Instruction in New York State High Schools," School Science and Mathematics, 69 (May, 1969), pp. 385-392.

PEABODY DEMONSTRATION SCHOOL (NASHVILLE, TENNESSEE)

This study investigated the effect of calculators on arithmetic achievement in grades six, seven, and eight. Thirty-five pairs of students were matched on intelligence and achievement measures and randomly assigned to experimental and control groups. The experimental groups used calculators for approximately thirty minutes each school day for a period of nine weeks.

Analysis of the data resulted in no significant effects of the calculator on arithemetic achievement. However, it did result in significant differences between experimental and control groups on a test of reasoning in the seventh grade. This points out the need for further research on dependent variables such as problem-solving and reasoning ability.

See-Victor R. Durrance, "The Effect of the Rotary Calculator on Arithmetic Achievement in Grades Six, Seven and Eight," Unpublished Doctoral Dissertation, George Peabody College for Teachers, (June, 1964).

SAN FERNANDO VALLEY (CALIFORNIA) STATE COLLEGE

A math lab was equipped with a number of calculators from various sources and one Olivetti-Underwood P101 (Programma) computer. The focus of the project was to motivate low achievers and to allow youngsters to concentrate on mathematics purposes and practices rather than to

devote their attention to mere arithmetic. The students using the math lab are given freedom to experiment on their own with help always available when needed.

The Sequential Test of Educational Progress of ETS was used as a means of evaluating achievement. "Achievement was excellent in comparison with previous years." Attitude inventories were administered to the 300 students and parents in the initial year of the project. The results were highly enthusiastic.

See-"High-achiever math-lab concept becomes project to assist the low-achievers," Educational Equipment and Materials, (No. 3, 1967), pp. 3-5.

WYNNE, (ARKANSAS) PUBLIC SCHOOLS- "USE OF CALCULATORS IN TEACHING MATHEMATICS."

This ESEA Title III project was designed to produce an outline course in general mathematics which would incorporate calculators. The purpose was to revitalize general mathematics for the non-college bound and, generally, non-motivated students who take the course.

The plan was to have demonstration classes in five Arkansas schools with one calculator available for every two students. The calculators were to be used for computation, thus, giving the student needed assistance in thinking through and solving problems.

See-Pacesetters in Innovation,V.I., Fiscal Year 1966. ERIC microfiche No. ES000529.

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